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Completed Research

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Abstract

Design Science is the process of solving 'wicked problems' through designing, developing, instantiating, and evaluating novel solutions (Hevner, March, Park and Ram, 2004). Wicked problems are described as agent finitude in combination with problem complexity and normative constraint (Farrell and Hooker, 2013). In Information Systems Design Science, determining that problems are 'wicked' differentiates Design Science research from Solutions Engineering (Winter, 2008) and is a necessary part of proving the relevance to Information Systems Design Science research (Hevner, 2007; Iivari, 2007). Problem complexity is characterised as many problem components with nested, dependent and co-dependent relationships interacting through multiple feedback and feed-forward loops. Farrell and Hooker (2013) specifically state for wicked problems "it will often be impossible to disentangle the consequences of specific actions from those of other co-occurring interactions". This paper discusses the application of an Enterprise Information Architecture modelling technique to disentangle the wicked problem complexity for one case. It proposes that such a modelling technique can be applied to other wicked problems and can lay the foundations for proving relevancy to DSR, provide solution pathways for artefact development, and aid to substantiate those elements required to produce Design Theory.

Keywords: Design Science, Wicked Problems, EIA Modelling, Relevance.

1 INTRODUCTION

The purpose of this paper is to illustrate how an Enterprise Information Architecture (EIA) approach helped to define, classify, document and communicate the nature and structure of a specific 'wicked problem'. Through this illustration, the efficacy of this approach to address wicked problems within Design Science Research (DSR), is demonstrated. Previous papers have communicated the characteristics of wicked problems, however, no study to date has provided methods for defining these wicked problems as part of a relevance cycle in DSR. This paper discusses the application of EIA in the Relevancy Cycle framework within Design Science Research (Hevner et al, 2007). In this research we show that 'wicked problems' results from a set of misaligned entities and systems within an organisation. These misaligned entities span across multiple layers of the enterprise, making it difficult for one person to articulate the nature and components of the wicked problem, as every stakeholder has a different perspective and experience. It is this misalignment of entities that prevents the enterprise from operating effectively or efficiently. This paper discusses the application of an Enterprise Information Architecture (based on TOGAF 9.1) to fully describe the wicked problem. By clearly describing the wicked problem this way, a number of further design advantages can be realised including: 1. the provision of the new artefact requirements according to misalignment of entities at each EIA layer; 2. the design pathways and solutions at each EIA layer can be readily defined; 3. the viability of each of these component layers can be separately evaluated; and 4. the scope of the artefact can be contained. From the Rigor Cycle perspective, within DSR, defining the wicked problem using this approach is also shown to help substantiate the elements and components required to produce DSR theory (Gregor and Jones, 2005; Walls, Widmeyer, El Sawy, 1992). This paper elaborates this approach and its advantages throughout this paper and makes recommendations of applying this approach to other similar wicked problems. The next section is the literature review, which is followed by the research method highlighting the importance of EIA modelling to the Relevance Cycle. This is followed by a description of the Design Cycle, and how EIA modelling facilitates design outputs. The subsequent section discusses the role of EIA modelling to producing Design Theory Outputs, as part of the Rigor Cycle. The last section is a summary, with recommendations, and concluding remarks.

2 LITERATURE REVIEW

Quality research is characterised as being both highly relevant, as well as having methodological rigor (Stokes, 1997; Winter, 2007). Recently, within the DSR community, the main focus for DSR has been on establishing methodological procedures, methodological rigor and the output of design theory. Little attention has been paid to establishing problem relevancy in DSR literature. The term relevancy in DSR has typically referred to the process of describing the IS problem, and its relationship to organisational effectiveness. It is the relevancy cycle, within DSR, that provides the platform for artefact development and the subsequent development of knowledge and/or theory. DSR has been historically bound to problems classified as wicked, as it is through solving these types of problems that new knowledge is attained.

In a comprehensive literature review on DSR methodology, Alturki, Gable and Bandana (2013) identified fifteen key DSR papers that explicitly discuss methodology. Of these, five papers briefly deal with the concept of problem wickedness and problem relevancy. These five papers, however, only briefly provide insight to the problem of establishing research relevancy (March & Storey, 2008; Peffers, Tuunanen, Rothenberger, & Chatterjee, 2007; Vaishnavi & Kuechler, 2004; Hevner, March, Park & Ram, 2004; Cole, Purao, Rossi, & Sein, 2005). A wider review of papers from the Engineering and Design fields reveals greater insights and perspectives into the nature and structure of wicked problems (such as Walls, Widmeyer & El Sawy, 1992; Eekels & Roozenburg, 1991; Nunamaker, Chen, Purdin, 1990; Takeda, Veerkamp, Tomiyama, & Yoshikawam, 1990). These papers also do not provide any detailed means for defining, classifying, documenting or communicating the nature of the wicked problem being addressed. They merely discuss what is and is not a wicked problem.

Recently, Gregor and Hevner (2013) touched on the importance of the relevancy cycle. In their paper they propose a DSR knowledge contribution framework. This framework classifies DSR knowledge contributions according to existing 'knowledge maturity' or problem conceptualisation. "Our framework focuses attention on the knowledge start-points (e.g., maturities) of the research project to support a clearer understanding of the project goals and the new contributions to be achieved" (Gregor and Hevner, 2013 p. 345). In DSR, it is within the relevancy cycle that the research problem and its relationship to the problem space can be conceptualised. It is in this cycle that the knowledge 'start-points' are defined.

Rittel and Webber (1973) first began to address the nature of wicked problems when discussing the formulation of social policy. In their discussion, they state that social policy problems cannot be definitively described, due to the complexity and pluralistic nature of these problems. They, therefore, coined these terms 'wicked problems'. Within IS research, these are generally the types of problems that are addressed through the development of bespoke Information Systems, though not all Information Systems development address wicked problems. It is the nature of identifying such problems and addressing them for which Design Science Research is particularly well suited (Gleasure, 2013). Rittel and Webber (1973) make a number of pertinent points about the nature of wicked problems in their seminal paper. Importantly they state that "the formulation of the wicked problem is the problem!" and "The process of formulating the problem and of conceiving a solution are identical" (Rittel and Webber, 1973 p. 161). They go on to say that the 'classical systems-approach .. is based on the assumption that a ..project can be organised into distinct phases. …. For wicked problems, however, this type of scheme does not work. One cannot understand the problem without knowing its context." (Rittel and Webber, 1973 p. 162). Their wicked problem space was planning in a social and economic setting, for which they argue have additional properties: there is no stopping rule; there is no true-false, but good-or-bad; there is no immediate and no ultimate test of a solution; the solutions are 'one-shot operations' as they have been implemented in a complex social setting, and thus cannot be undone; their solution space is not enumerable; they are essentially unique; they can be seen as symptoms of another problem. Richardson (2014) said key characteristics of a wicked problem are its extreme degrees of uncertainty, risk and social complexity. Buchanan (1992) (citing Rittel and Webber 1973) states that wicked problems are a 'class of social system problems which are ill-formulated, where the information is confusing, where there are many clients and decision makers with conflicting values, and where the ramifications in the whole system are thoroughly confusing."

Soft systems approaches were developed in part to deal with these 'ill-defined, messy or wicked problems' (Checkland 2000). The main argument in Rittel and Webber's 1973 paper was the classical (hard) systems approach could not be applied to the emerging class of 'wicked problems'. One means of articulating the environment within which problems can be identified is through the application of Enterprise Information Architecture approaches. Robertson-Dunn (2012) suggests that 'a problem-oriented approach to Enterprise Information Architecture can deliver a better outcome than one based on needs and requirements, especially when dealing with Wicked Problems'. Robertson-Dunn goes onto say (2012, p.68) that 'as information systems become larger and more complex, systemic non-linearities due to issues such as scale, speed of change and response times start to dominate. This leads to problems with many of the same characteristics as those found in the social context', and as 'information and communication systems move out of the purely technical and data processing worlds into an online environment … , the more the problems become wicked.'

The characteristics listed by Robertson-Dunn (2012) of Wicked Problems are those experienced in many large information systems led innovation projects within the public and private sectors. It was these characteristics that led to the selection of an Enterprise Information Architecture approach within a Design Science Research framework to address the complex social and cultural elements driving the application development in one organisation. Historically in IS research, artefacts have been viewed as separate to the human experience. More recently, however, many authors have expressed that both IS problems and artefacts should be viewed as part of, and not separate to sociotechnical spaces: "The objectives of IS design science research is to develop practical knowledge for the design and realization of different classes of IS initiatives, where IS' are viewed as sociotechnical systems and not just IT artefacts" (Gregg, Kulkarni, Vinzé, 2001).

Considering the above statements, assuming that it can be argued that wicked problem are not separate to but exist within a problem space, a number of points can be raised: a problem space can be defined by abstract components (entities), their attributes or both (see Takeda, Veerkamp, Tomiyama, & Yoshikawam, 1990). The entities can be classified as an IS, IS-user interaction, or user related (McKay, Marshall & Hirschheim, 2012; Dourish, 2004). Wicked problems may be resultant of a 'misalignment' between multiple entities and their attributes caused (in part) by the ill-defined relationships between multiple entities. This 'misalignment' leads to decreased efficiency and effectiveness within the problem space. Misalignment of these entities and attributes can be either directly or indirectly observed (Nunamaker, Chen, & Purdin, 1990). The relationships between these entities and attributes can be difficult to define due to agency finitude, problem complexity and normative constraint (Farrell and Hooker, 2013).

In Rittel and Webber's (1973) conception of wicked problems, there was an observation that there was a difference in cognitive processes when solving Design (wicked problems) and Science Problems (tame problems). Hooker and Farrell (2012) dismiss this notion. In their analysis of Rittel and Webber's (1973) paper, Hooker and Farrell (2012) define and reduce the characteristics of wicked problems from ten characteristics to three core human attributes, and show that these attributes are common across both Science and Design problems. Hevner, March, Park and Ram (2004) similarly define wicked problems by their attributes. Based on the work of Brooks (1996), Brooks (1987), and Rittel and Webber (1973), Hevner et.al. (2004) identify five core attributes of a wicked problem. Farrell and Hooker (2013) show that these five attributes can further be condensed to the attributes of human finitude, problem complexity, and human normativity.

Human finitude is defined as the limits and bounds that are placed on the agent defining and understanding problems. It is recognised that human finitude can be cognitive in nature (ignorance or limited cognitive capacity), or social/political in nature, which implies limited resources and/or time constraints. Whenever there is a limited set of resources that limits the production of an optimal solution, the problem must meet at least one of the two required conditions in order to be classed as a wicked problem. According to Farrell and Hooker (2013) this attribute is a compulsory condition for problems to be classed as wicked. A second attribute of wicked problems is complexity. Complexity, within the organisational context, will typically involve many organisational entities and their relationships. Multiple entities may belong to multiple layers of the problem space, and they may have multiple dependencies and co-dependencies. Finally, wicked problems may be described as being in a state of normativity. This phenomenon arises when stakeholder values, and social and cultural norms further complicate the exact identification of the problems and their various solution paths.

Assuming that wicked problems cannot be separated from the problem space, defining the problem space becomes an integral part to defining the 'wicked problem' and operationalizing a potential solution. We propose that the definition of the problem space can best be completed through using an EIA modelling technique as defined by the Open Group Architecture Framework (TOGAF 9.1). Rittel and Webber (1973), states that every wicked problem is unique, and every solution is a 'one shot operation'. This position does not limit the application of EIA to delineating wicked problems. In addition, this paper argues that DSR can benefit from using such an approach to define, classify, document, and communicate the nature of a wicked problem and their solutions. Using TOGAF standards to model the wicked problem as part of the problem space not only 'tames' the wicked problem (i.e., addresses the issues of human finitude, problem complexity, and human normativity), but it provides a mechanism for establishing the artefact's relevancy in DSR, as analysis of the Business, Information Systems, and the Vision/Strategy layers in the Enterprise reveals the problem's significance and context. Secondly, it can clearly generate defined pathways for Information Systems (IS) artefact development. Thirdly, it can help substantiate those elements and components required to produce DSR theory (Gregor and Jones, 2005; Walls, Widmeyer, El Sawy, 1992). This study provides the first example, of such an approach, to modelling a wicked problem using EIA TOGAF standards.

3 THE CASE CONTEXT

This research is concerned with the development of a new set of IT artefacts complementing organisational processes and systems within the context of a large, co-educational school providing education, complemented by a rich set of co-curricular and pastoral care services for grades 5-12. The school is independent within the Catholic education system and espouses an education that is Catholic and Franciscan. It encourages its students to achieve personal bests and to develop skills through its co-curricular activities of music, sport, drama and service. In addition, it has a very strong pastoral care system that it seeks to support through a richer reporting of behaviour management. There are many stakeholders in this system, often with conflicting views. This situation reveals a wicked problem, as described by Rittel and Weber (1973) and Buchanan (1992) for it belongs to that "class of social system problems which are ill-formulated, where the information is confusing, where there are many clients and decision makers with conflicting values, and where the ramifications in the whole system are thoroughly confusing". There are many clients including the teachers, the parents, the pastoral care staff and the senior management of the school. Each has a different set of requirements of and expectations for such a system. Behaviour Management systems historically have tracked negative behaviours and the application of a scaled set of responses. The philosophical orientation of the school staff was towards improvement, so a new system tracking and rewarding positive behaviour was conceived. In addition, the system needed to work in the co-curricular environment, which often was not in a classroom. So additional features provided through the 3G and 4G mobile environments were also utilised to provide system access in the public and sporting spaces often used in the delivery of the co-curricular experiences. These technologies increased the complexity of the system, and matched the observations of Robertson-Dunn (2012) of becoming "larger and more complex" and "systemic non-linearities" were encountered "due to issues such as scale, speed of change and response times". This problem was conceived as a research problem, amenable to the application of Enterprise Information Architecture approaches and informed through the application of Design Science Research; DSR as the research method is next discussed.

4 METHODOLOGY

The Design Science Research Methodology was selected for this research as there were critical social, cultural and educational reasons for undertaking this study. These components were reviewed and revealed through the application of the Relevance Cycle. This led to the clear articulation of the design attributes for the set of artefacts required to deliver the technical solution, the educational solution and to address the cultural and social goals of the project. The application of the Rigor cycle led to the identification of rigorous means of evaluating the effectiveness of the solution set and the articulation of research results. Although many other Design Science Research studies use varying steps within their methodology they generally subscribe to these three cycles: relevance, design, and rigor (Aken, 2004; Baskerville, Pries-Heje & Veneable, 2009; Cole, Purao, Rossi & Sein, 2005; Gregor & Jones,2007; Hevner, March, Park & Ram, 2004; March & Smith, 1995; March & Storey, 2008; Peffers, Tuunanen, Rothenberger & Chatterjee, 2007; Pries-Heje, Baskerville, & Venable, 2008; Rossi & Stein, 2003; Viashnavi & Kuechler, 2006; Veneable, 2006; Walls, Widmeyer, & El Sawy, 1992). Within each of these research stages, further research methods are adopted. The framework used in this study, is adopted from Alturki, Gable and Bandara (2013). The methodological framework used for this study is presented in Figure 1, which shows the three distinctive cycles of the Design Science methodology: Relevance Cycle, Design Cycle and Rigor Cycle. The research methodology for this study highlights the importance of defining the wicked problem as part of the relevance cycle.

4.1 Importance of the Relevance Cycle in DSR

The methodology used in this study, although adopted from Alturki, Gable and Bandara (2013), differs, in that emphasis is placed on defining the wicked problem, through defining the relationship between the wicked problem and the problem space in which the problem exists. This analysis of the underlying wicked problem was completed using EIA modelling standards from TOGAF 9.1. The EIA developed as part of the Relevance Cycle is used directly to define the artefact requirements. A set of services was developed to deliver the information effect required for the technical solution. A set of training activities was developed to migrate the staff (teaching, pastoral care and management), in the use of these systems. A set of evaluations were conducted to determine the efficacy and adoption of the new systems through identifying and applying accepted measures, such as the IS-Impact instrument of Gable, Sedera and Chan (2008), and the Unified Theory of Acceptance and Use of Technology (UTAUT) instrument by Venkatesh, Morris, Davis and Davis (2003). In addition, user attitude is assessed through a series of convergent interviews. These quantitative (IS – Impact, UTAUT) and qualitative studies (Convergent Interviews) provide data that aids in the refinement of the initial solutions to an elegant solution from an end user perspective.

As Figure 1 shows, when the wicked problem and the problem space is modelled using EIA-TOGAF standards, the wicked problem can be deconstructed and 'tamed'. The development requirements for the novel artefact can be highlighted, various alternative components of the artefact can be evaluated, and the research and development scope can be defined and contained. These advantages derived from modelling the problem and problem space are discussed later sections.

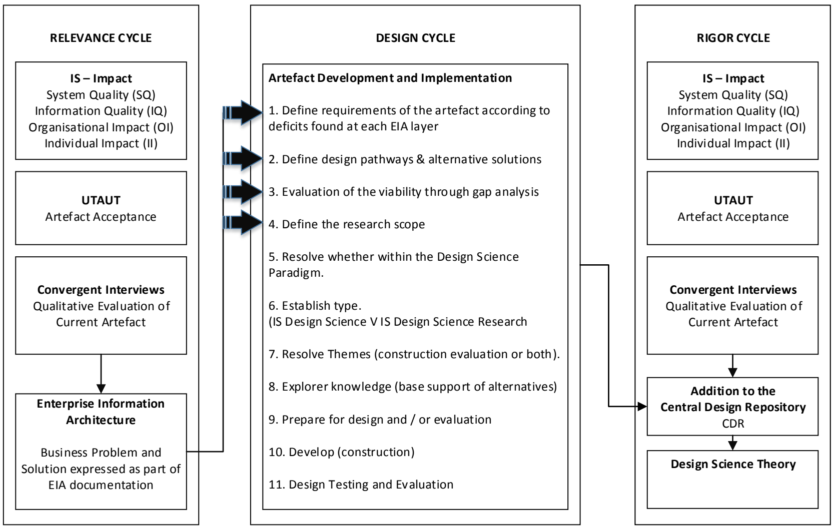

Figure 1. Research Methodology

4.2 Design Cycle Outcomes

Another key attribute that defines this problem as wicked, is the necessity to develop novel artefacts for problems that do not have standard or existing solutions. A novel solution for this research has been designed, developed and instantiated. This artefact is represented pictorially in Figure 2.

Figure 2. *Graphical representation of system architecture*

The primary function of this software artefact was to enhance a teacher's ability to continuously collect data on student behaviours within, and external to the classroom. A component not previously available in IS software, but developed for this project, is the 'proximity detector'. The proximity detector is an algorithm that triangulates the Radio (Received) Signal Strength Indicator (RSSI) of multiple Bluetooth signals (BTLE 4.0) from multiple Slave iOS devices; in this case the iPad 3.0. By successfully implementing the 'proximity detector', the closet Slave (student) iPad, to the Master (teacher) iPad could be determined. In IS software that uses a relational data model, the user is always required to look up the 'key parent field', before data can be entered against the 'child field'. Using this relational model, a teacher is required to make three user transactions per data entry. With the use of mobile technology and the 'proximity detector' it is theoretical possible to automate and pre-populate the field lookups, thereby reducing the number of user transactions in behaviour reporting, for a given data set, from three interactions to one. In practical terms, the Bluetooth signal algorithm, recognises the closet student mobile device to the teacher mobile device, and through this trigger automates the lookup of the student in the IS, so that data can be applied to that student's records.

This project design, developed and instantiated two mobile apps (master and slave) that automates the 'Parent key field' lookup in relational information systems. By doing so the number of classroom transactions required, per data entry, is reduced from three to one. In addition, the application is accessed through the use of either an iPad or iPhone facilitating data capture in public and sporting spaces. Daily reports are generated for pastoral care and administrative staff, as well as information emails and texts generated to the parents or care-givers of reported children, for both positive and negative behaviours. As well as containing this novel component, the developed artefact incorporated all of the design considerations documented in the strategic, business, application and data/physical layers, which were realised as a set of web services. The business goals for the school were achieved as recommended by Robertson-Dunn (2012), through the articulation of the information needs for these business problems. Robertson-Dunn (2012) system for a problem-oriented approach to EIA is shown in Figure 3.

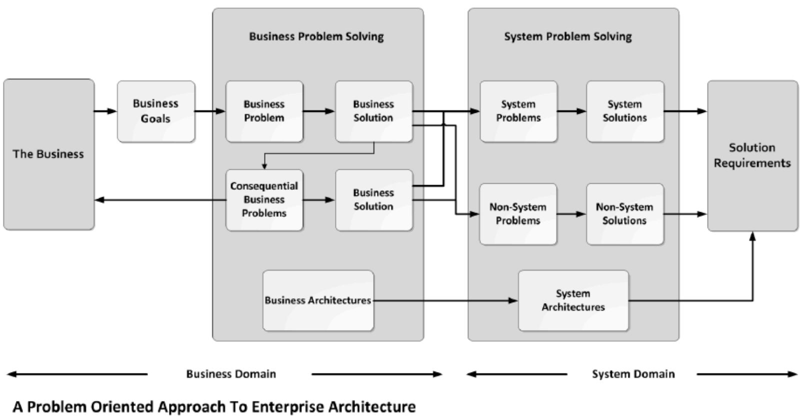

Figure 3. *A Problem Oriented Approach to EIA (Robertson-Dunn, 2012, p. 61)*

The approach to defining the problem space using EIA approaches is discussed in the next section.

4.3 Defining the Problem Space using TOGAF 9.1

Enterprise Information Architecture (as defined by ANSI/IEEE Std 1471-2000), is the "fundamental organisation of a system, embodied in its components, their relationships to each other and the environment, and the principles governing its design and evolution". An Enterprise Information Architecture model usually represents the current and or the desired architecture states of the organisation. IS in an Enterprise, as defined by TOGAF, is represented by the following four layers of architectural abstraction: the Architectural Vision Layer, Business Layer, Information Systems Layer, and the Technology Layer. Within each of these abstract enterprise layers, an EIA identifies the entities and their attributes, within that layer. The relationships between each of these entities are modelled to highlight gaps or misalignments between each of the entities and the entity groups. These relationships are usually represented through the process of applying modelling techniques that are part of the TOGAF standard. The purpose and structure of the EIA layers are forwarded to highlight how each of the layers of an EIA can define the entities and their relationships to other entities within the domain or problem space.

The first layer of the EIA, described in this paper, is the Architectural Vision Layer. The design of this layer requires the identification of the potential uses of information technology in the organisation as well as their limitations. Within this layer, the vision statement of the organisation is usually deconstructed, and through documenting each of the layers, the ability of each service unit to meet the defined organisational goals are measured through the corresponding performance indicators.

Within the Business Layer, the business services, business functions, and business processes are positioned. A business service is defined as the value a business unit delivers to the identified stakeholder. A business function is defined as a grouping of similar business services, such as employee services. A business process is defined as a number of defined and structured activities that produce and deliver specific services or products for stakeholders (Weske, 2012). When developing a business layer, five different views in this research are utilised to aid in the conceptual understanding of the Business Layer. These views are: Value Network View, Service View, Process Control View, Business Process View and the Balanced Scorecard View. The Value Network View is initially used to show the relationship between the Business Functions and the Business Services. The Service View describes the strategic alignment of a Business Function, Business Service, Service Units and Business Processes. The Process Control View provides a high level view of Business Processes and the applications that support those Business Processes. The Business Process View details Business Processes by defining the sequence and combination of actions, performance indicators and their triggers. The final view developed is the Balanced Scorecard View. Within this view performance indicators/success factors are defined for specific business processes.

The purpose of the Information Systems Layer in an EIA is to define what kinds of software applications are relevant and can be consumed by stakeholders in the organisation. These software applications are described in terms of how the applications support both the information objects in the data layer and business functions and processes in the corresponding business layer. The application layer is usually modelled using the Landscape View. The Landscape View documents all of the applications needed and their relationships, in order to deliver the Service to the stakeholder. Through the functional landscape view, data ownership and functional reuse is recognised.

The goal of the Technology Architecture layer is to define the data entities for each of the key services of the Enterprise. A multitude of views can be constructed to model the data architecture, including UML modelling, Use Case View, Use Case Description and a Static Structure View etc.

This section has provided a brief summary of the purpose and structure of Enterprise Information Architecture. It should be noted that this brief introduction into EIA modelling is not comprehensive. Further models may be adopted to describe entities and their relationships across each of the abstract layers of the EIA. For each of the entities and their relationships within an EIA, gap analyses can be performed between the current and desired states. Further models can be developed, to view the dependencies of these gaps and how each of these gaps relate to each other. A key function of EIA is to provide effective measures for the quality of relationship between each of the enterprise entities. These measures include KPIs and the Balanced Scorecard. These may be particularly useful as a quantitative or qualitative measure in determining the effectiveness of the new artefact.

4.4 'Taming' the Wicked Problem using EIA Modelling

The purpose of this section is to describe the wicked business problem that is of focus in this research. This business problem is classified as wicked one because it has multiple dimensions that span across multiple EIA layers, within the enterprise. To fully define this problem, its complexity is deconstructed through aligning the problem entities and their relationships, to the EIA abstract layers. For each layer, the convolution of the problem is discussed and the agent finitude and problem normativity is inferred. Through undertaking this process, a method for defining wicked problems is illustrated.

A goal for any organisation, including Education, is to implement Quality Systems. Accountabilities and standards are met through these 'Quality Systems" (Deming, 1986). The implementation of any quality system in schools needs to be implemented from a systems perspective ensuring 'cyclical action learning' and process improvement. "Total Quality Management (TQM) can help schools systematically bring about change: Its holistic approach accents system theory. Its tools provide vehicles for data analysis and decision-making. Its principles accent the importance of each person in the system to strive for continuous improvement" (Berry, 2002, pp. 203). Total Quality Management has been a priority issue in education since its adoption in management (Abernathy and Serfass, 1992). Within education there are numerous cases where there have been attempts at improving quality, or at implementing a quality improvement program. Many of these programs fail, or make little difference to the outcome of the quality of education for students. The main reason for these failures centres on the lack of understanding of the definition of quality, and a lack of understanding of how to implement an effective TQM within an education system (Cheng, 1997). An important part of TQM philosophy is the process of continuous improvement (CI) because, through feedback loops, both teacher practice and student behaviour are iteratively improved. In complex organisations such as schools, a successful CI program requires an automated continual flow of data across many stakeholders (Saiti, 2012). This continual flow of data is reliant on the collection of data within the classroom, where the student behaviours are being observed.

The purpose of this research was to investigate those issues that prevent a continuous cycle of quality information and through IS enabled innovation, seek improvement in pastoral care services. Pastoral care at the school entails delivering three key services to students: incident management, case management, and proactive programs. The business processes that make up these services require contributions from other service units such as the curriculum services unit (staffed by teachers), and the student services unit (comprising various counsellor types). Through the use of EIA models, a misalignment in practice between the service units and their role in the defined business processes was identified. The first part of the wicked problem, therefore, relates to quality of information (feedback and feed-forward) between each of the service units. In particular, it was found that teachers (curriculum services) do not provide consistent information to pastoral care services for the effective decision making across the three key Pastoral Care Services i.e., incident management, case management, and proactive programs.

At the Information Systems layer, it was found that teachers were not using the existing IS application to record behaviours within the classroom. The use of this IS was perceived to detract away from the teaching and learning process. To report behaviour incidents, teachers were required to look up the student (parent field), look up the incident, and then assign the incident to the student. This required three interactions for a single data transaction, and shifted attention away from the primary task of teaching. This lack of data collection then negatively impacted resultant behaviour management processes. The evidence collected from convergent interviews also showed problems with the utility of the IS. The existing IS did not incorporate best practice principles as part of the design of the application. In the view of teachers, this made the application of questionable value, even though pastoral care services depended on the data collected and reported by the existing IS.

In the initial phase of EIA development, there were no documented requirements for change between the current and desired states at the Technology layer. After choosing the most appropriate pathway recorded in the alternative pathways register, however, the development of a web-services layer was identified as a requirement. In addition, a different data collection system was identified and required which could use the advantages and sensors within mobile and Bluetooth technologies.

4.5 EIA as a means of understanding a wicked problem

It has been proposed that wicked problems in Information Systems can be addressed through articulating the key components of a wicked problem through the lens of an Enterprise Information Architecture. The previous section conceptually described a wicked problem using an EIA framework, and thus showed how models and techniques can be used to identify the entities, their attributes and the relationships between entities, within the problem space. A wicked problem was seen to have the following properties: 1. Addresses a class of ill-formulated social system problems, 2. Have confusing and contradictory information about the problem, its purpose and its constraints, 3. Has many clients and decision makers with conflicting values and 4. Where the ramifications in the whole system are thoroughly confusing. Considering these characteristics of a wicked problem, the use of the EIA provided the process and the tools to describe the nature of this ill-formulated social system. In the example provided, the wicked problem was described as a group of entities within each enterprise layer. EIA modelling, with its established procedures and models, aided in defining the entities and the relationships between these entities. This research was able to utilise these models to define the wicked problem. Given that the relationship between the wicked problem and the problem space was defined, the boundaries and scope of the research were also established. One of the positive attributes of an EIA is that a multitude of models can be utilised. Using models, facilitates the communication of the enterprise objectives from various perspectives. For example, typically the information technology (IT) staff in an enterprise, view problems from the physical, data and application layers, the end users from an application and business layers, and management from the strategic layer. Using models at each layers, facilitates and understanding between each of the perspective thus aligning the outcomes at each strategy layer. This reduces the complexity, thus confusion in the problem space.

4.6 EIA as a mechanism for proving problem wickedness and relevancy

Considering the three stated attributes of wicked problems, the use of an EIA provides both the method and the tools to map and model organisational attributes and their complex relationships, and address the issues of human finitude, complexity and normativity. Furthermore, given that entities, abstract concepts, and their relationships can be identified (Takeda, Veerkamp, Tomiyama, & Yoshikawam, 1990), modelling the current and desired enterprise states will subsequently allow for the identification of gaps between these two states as well as facilitate the identification of the wicked problem elements influencing these states. The skilled Design Scientist can then design and develop solutions that addresses these identified gaps. The process of developing an EIA can potentially help the Design Scientist define problem complexity, and reduce cognitive loads in identifying and describing complex organisational problems. An EIA can be viewed as the roadmap for IS change in an organisation. By developing an EIA document, a clearer understanding of these entities and their relationships can be communicated to stakeholders. An EIA, therefore, also has the potential to reduce normativity risks associated with organisational problems. Once the wicked problem is defined by its components, and their relationships to one another, the development pathways for artefact development can also be more clearly defined.

4.7 EIA as a mechanism for stimulating design pathways for artefact development

Artefacts are built for the purpose of improving organisational activities (Tsichritzis, 1998; Denning, 1997). The scope of an artefact can be defined by the bounds of the organisation, and its respective organisational layers (Winter, 2008). Figure 3 shows the potential scope for artefact development by defining its bounds through the various EIA layers. A number of benefits, from a development perspective, can be realised by defining the problem in this way.

When an artefact is developed in response to a wicked problem, rarely it will need to address only one design consideration. Usually there are multiple design considerations across multiple layers of the enterprise. Like an enterprise, most artefacts will consist of multiple architecture layers. By grouping the components of the wicked problem into 'like' groups, the designer is able to determine the most suitable architecture of the artefact, and what components will need to be addressed at each architecture layer. The suitability of various types of technology can also be more readily discerned, given that a clear understanding of the scope and structural requirements for the artefact, are provided. Additionally, through defining the wicked problem using EIA standards, potential solution pathways can be identified by iterating through those entities and their relationships that are misaligned. This iteration process can be seen as a creative exercise, determining how a new artefact may work across the various entities and their relationships. For each iteration, the researcher can identify possible uses of technology that can be utilised for each pathways, and document its applicability and limitations. These steps provide rigour to the artefact development process (Alturki, Gable and Banadara, 2013). The research defined the documented gaps across each of the EIA layers for the targeted Service unit, namely the Pastoral Care Services unit.

Documenting the Gaps across each of the EIA Layers for a defined Services unit.

Phase	CURRENT	DOCUMENTED GAPS	DESIRED
Strategy Layer	Vision for the Pastoral Care of students documented in the Enterprise Information Architecture (EIA)	Gaps are identified at the Business, Application and Data Layers	Software design incorporates the vision for the Pastoral Care of students in all aspects of the design
Business Layer	Current Business Processes are documented in the EIA	Identified Business Processes are redesigned	Documented Business Processes are incorporated as part of the IS Design
Application Layer	Current application architecture and design are documented in the EIA	Reasons for resistance to use of application in classroom documented through: 1. Interviews 2. SQL Data Analysis 3. UTUAT & IS-Impact Scales	Optimal Software Architecture & Optimal Software Application Design incorporated into a Solution. Novel Solution incorporated into design to overcome problem not solved using established technology
Data / Physical Layer	Current data / physical architecture and design are documented in the EIA	Web Services Layer introduced into the architecture	Normalised data, with optimal data retrieval processes. New approach to data triggers for Stored Procedures (mobile technology)

Table 1. EIA Gap Analysis:

5 EIA AND THE RIGOR CYCLE

From this analysis, the power of the EIA to address the critical components of design science has been demonstrated. The elements of wickedness have also shown to be effectively addressed through the rigorous application of EIA methods. The resultant Information System is the sum of the artefacts revealed through this analysis. This system has been deployed and its effects on teacher reporting, student behaviour and pastoral care management are the subject of the next phase of the research. This section addresses how the use of the EIA has facilitated the development of theory as a result of the instantiation of the IS artefact. The EIA developed in this case study, has addressed all the required elements to define, delineate and develop design science research theory. This section contains eight parts, each part listing the elements of, and outputs of DSR, as advocated by Gregor and Jones (2005).

According to Gregor and Jones (2005), the DSR theory element '*purpose and scope'*, defines the relationship between the artefact and its environment. The nature of this relationship defines the boundaries of the research and, therefore, the boundaries of the theory being evaluated. Within this research, the strategy layer of the EIA defines the problem space. The relevancy cycle within DSR is defined as the process of identifying multiple entities that are related through their participation in a common function. This function may have a micro or macro focus. This function is theoretically aligned with the goals outlined in the strategic layer, however, the ill-defined relationship between the multiple entities and their attributes, prevents the goals stated in the strategic layer from being realised. The scope of the artefact design is established addressing these misalignments. The relationship between the artefact and its environment is facilitated and clearly established through the use of EIA.

To clearly define relationships between entities, as well as the artefact to its environment, it is vital that the *constructs* used in the research are clearly defined. Walls, Widmeyer, and El Sawy (1992), based on work from Dubin (1978), state four considerations for describing constructs: the units of interaction; law of interaction between the units; boundaries to which the theory is expected to hold; and system conditions where the theory is not expected to hold. The example provided in this study used the techniques in TOGAF EIA to deconstruct the problem space. Through undertaking this process, the units, and their interactions were described. Through focusing on problem interactions between units, the laws that drive these interactions were defined and redefined through research testing. Through applying research, to these defined 'laws of interaction' the application and limitations of these laws of interaction were also defined.

Once the constructs of the problem space are defined, they can be used to describe the architectural and functional structure of the artefact. The purpose of the DSR theory output '*Principles of Form and Function*' is to describe the artefact by mapping its conceptual structure, functions, attributes and properties (Gregor and Jones, 2005). Table 2 shows a concept map developed as part of this research. It provides a conceptual overview of the artefact's form and function. The artefact is described as an IS Object Design (Using van Aken's (2004) classification), at the application layer and data layer. The artefact incorporates a process redesign at the business layer. The artefact is developed for the purpose of meeting the realisation design described in the strategy layer. Further detailed elaboration on the design, is completed in the research, in the context of the problem space. This problem space was described using the EIA. This table represents structure of an instantiated artefact for this research. The entities and components of the wicked problem are categorised according to the abstract layers of an EIA. For entities, in each EIA layer of the wicked problem, the artefact component is described.

	DIMENSION		
WICKED PROBLEM TYPE	**Physical Component**	**Human Computer (HCI) Interaction**	**Human**
Strategic design		*Realisation Design*	
Business design		*Process Design*	
Application design		*Object Design*	
Data design of components in the Enterprise	*Object Design*		
Physical design of components in the Enterprise			

Table 2. Artefacts instantiated for this research

Testable propositions or hypotheses about an artefact's effect on the problem space is an important part of establishing design theory (DT) in DSR; Gregor and Jones (2005) state that "these propositions can take the general form: If a system or method that follows certain principles is instantiated then it will work, or it will be better in some way than other systems or methods." Considering the artefact example in Table 2, the testable proposition is that an artefact with the specific architecture as defined in the Business, Application and Data Layers, will have an effect on specific goals stated in the strategic layer. Specifically, with the use of Bluetooth sensors, the number of user interactions per data entry can be reduced thereby facilitating increased use, and better quality behavioural outcomes for students. The success in achieving those goals in the strategic layer are measured through both qualitative and quantitative measures established at the start of the project. Walls, Widmeyer, and El Sawy (1992) define design theories as "composite theories that further encompass those kernel theories from natural science, social science and mathematics". They differentiate design theories from natural and social sciences in that design science is the application of natural and social sciences in practice. Through applying these theories in practice, empirical support for that theory can be obtained. The use of an EIA in this research allowed for the easy identification of those natural and social science theories that needed to be further explored and tested as part of DSR. The kernel theories, explored for this research, aligned to those goals that are outlined in the strategic layer.

For the purposes of this research, the *principles guiding artefact development* were determined from an analysis of those gaps that exist in the problem space. A review of the dependencies and co-dependencies between each of the entities was initially completed. The entities, or group of entities that were identified as having the greatest number of dependencies, became the initial focus for design. A review of the solution pathways was then conducted to review whether there was a need to develop novel solutions to the identified focus problems. A cascade approach for development was then undertaken. Through using this approach, we saw that the core of the wicked problem was addressed, with all other dependencies appropriately documented, and included as considerations in the design and development of the novel artefact.

6 CONCLUSIONS

This paper has discussed the importance of wicked problems in DSR by describing what a wicked problem is, and has discussed it properties according its definitions. Importantly, it was shown that wicked problems are not separate to the problem space and, therefore, to define the wicked problem, the problem space within which it exists also needs to be defined. By achieving this, the entities, their relationships, and the resultant complexity of the wicked problem could be discerned. This paper introduced the value of completing an EIA in order to define entities, attributes and their relationships. The EIA aids in identifying the misaligned entities, their attributes and relationships through the use of standardised modelling techniques. Multiple models provided a number of different views in which the problem can be examined. Modelling the differences between the current and desired problem space highlights the gaps that exists between these two states. Being able to identify that existing technology cannot bridge these gaps proves novelty of the artefact. Section 5 discussed how the development of an EIA provided direction and facilitated the output of design theory, which included: 1. The purpose and scope of the project; 2. A description of the construct produced; 3. The principles of form and function; 4. The artefact mutability; 5. Testable propositions; 6. Justificatory knowledge; 7. The principles of implementation, and 8. The expository instantiation.

A case study was presented which detailed the EIA and the resulting systems that addressed the elements of human finitude, complexity and normativity. This approach allowed clarity of purpose for the system as seen from the different stakeholder perspectives that informed the detailed system design, development and implementation. Assessment of the effect of the new system on teacher student behaviour and its effect on pastoral care is the subject of the next phase of this research project. This paper discussed how the EIA led to a taming of a wicked problem. It presented the key problem components of the case study to show that the research problem was a wicked problem in the multiplicity of stakeholders, with conflicting system expectations and experiences. The 'wickedness' was compounded by the need to have a system that was online, able to be used in a variety of physical settings, encouraged data input by the teacher practitioner of both positive and negative behaviour observations. A variety of reports were generated in real time to the teacher, the pastoral care teacher, school administration and the primary care givers of the student. The capture of the business goals in terms of its cultural and religious charter was critical to achieve system success and system adoption. The need for evaluation of system efficacy and acceptance was identified and included in the rigor cycle of the research design. This evaluation is still on-going. Finally, the utility of the application of the Enterprise Information Architecture in substantiating those elements required to produce such a design theory was discussed and the elements needed to produce design theory as described by Gregor and Jones (2005). For each design theory element, this paper showed how EIA modelling facilitated the production and proof of these design theory elements and tame a wicked problem.

The limitations of this paper are apparent when considering its applicability to other wicked problems. The principles forwarded in this paper are best applied to those wicked problems that occur as a result of misaligned entities within the Enterprise. The EIA framework does not apply to more abstract problems, IS problems not specifically related to Enterprises, or where solving the problem may require a radical departure from the norm. For 'new solutions for known problems' and 'known solutions extended to new problems' (Gregor and Hevner, 2013), this paper offers an approach to define, classify, document and communicate the nature and structure of a specific 'wicked problems' in an Enterprise context.

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